

# **SWIR SKY GLOW AND CLOUD COMPARISON BETWEEN URBAN AND RUAL MEASUREMENTS**

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# **SWIR Sky Glow and Cloud Comparison Between Urban and Rural Measurements**

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# Introduction



- **Low Light Passive SWIR Imaging**
  - Natural Night Time Sources
  - **SWIR Sky Glow**
    - High Altitude Chemical Luminescence
  - Cloud Reflection
  - Moon
- **Sensors Unlimited SWIR Camera**
  - 50 e- Noise per Pixel
  - F/1.4 Lens

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# SWIR Sky Glow

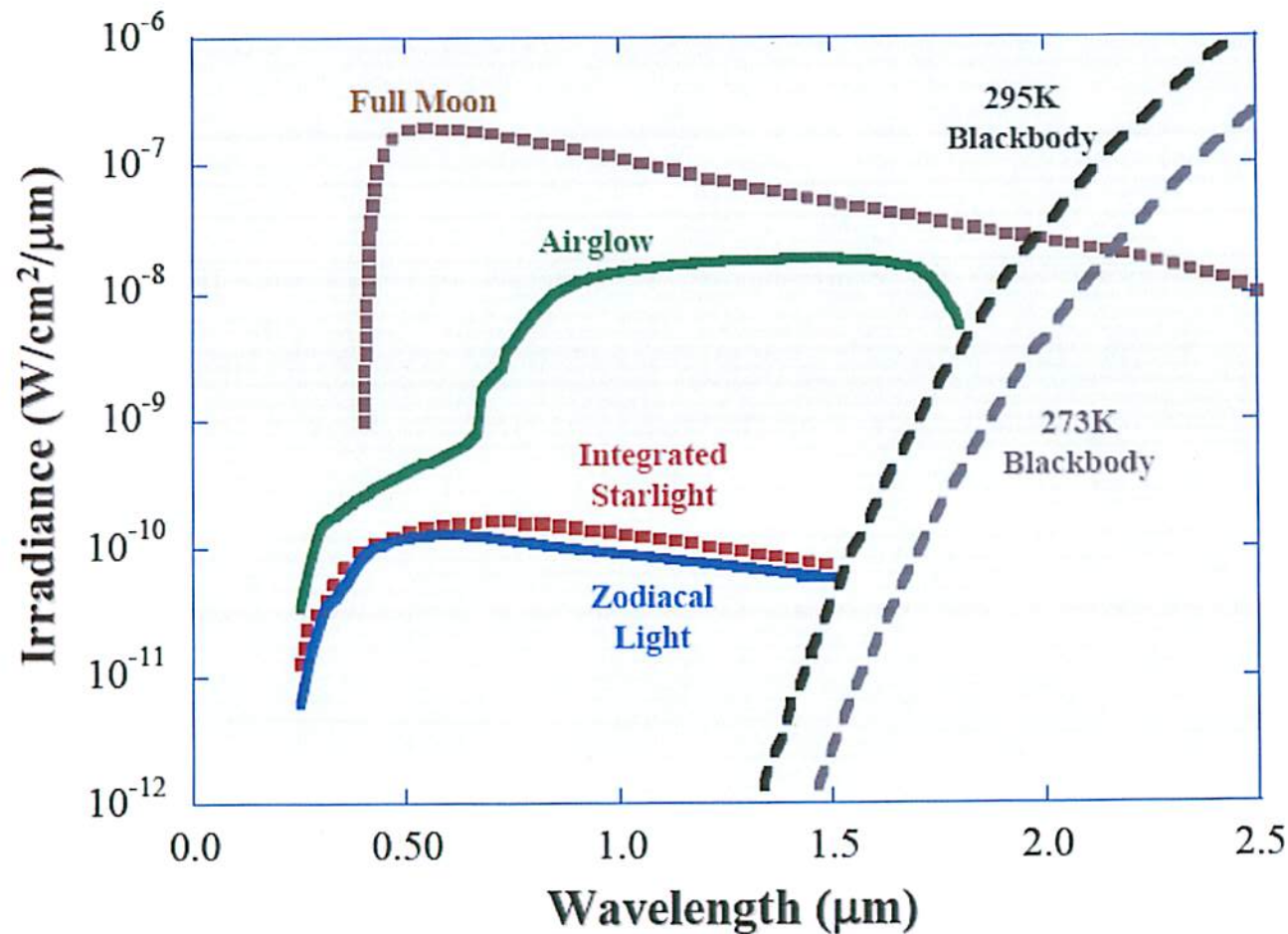


- **SWIR Sky Glow**
  - **Vibration and Rotation States of Hydroxyl OH**
  - **Complex Chemical Interactions Involving Ozone**
    - UV Radiation Charges During the Day
    - Reverse Process Produces SWIR photons at Night



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# Natural Night Sky Irradiance Sources



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# SUI 320KTX Camera



- 320x240x40 $\mu$ m pixels
- 50 e- Read Noise  
2.3x10<sup>-10</sup> NEI
- Rolling Shutter
- Spectral Response  
0.9 – 1.7  $\mu$ m

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# Measurements



- 
- **Collected Between 11 Pm and 1 Am**
  - **No Moon**
  - **Partly Cloudy Conditions**
    - **City Lights Reflected from Cloud Bottoms**
    - **Mie Scattering varies with Scatter Angle**



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# Bar Chart 100 Yds 5" Separation



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# Bar Chart 200 Yds 5" Resolution





# Comparison with Intensified CCD Camera

Note: Excess Noise (Scintillations) in ICCD Camera



ICCD Camera



SWIR Camera

Irradiance  $\sim 1.2 \times 10^{-8} \text{ W/cm}^2$

# Image Comparison Near Horizon

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## Looking Away from City

(~ 20 Deg)



ICCD Camera

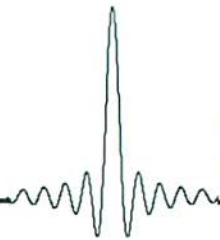


SWIR Camera

Sky Glow Radiance  $\sim 2.9 \times 10^{-8} \text{ W/cm}^2$   
Cloud Radiance  $\sim 3.5 \times 10^{-9} \text{ W/cm}^2$



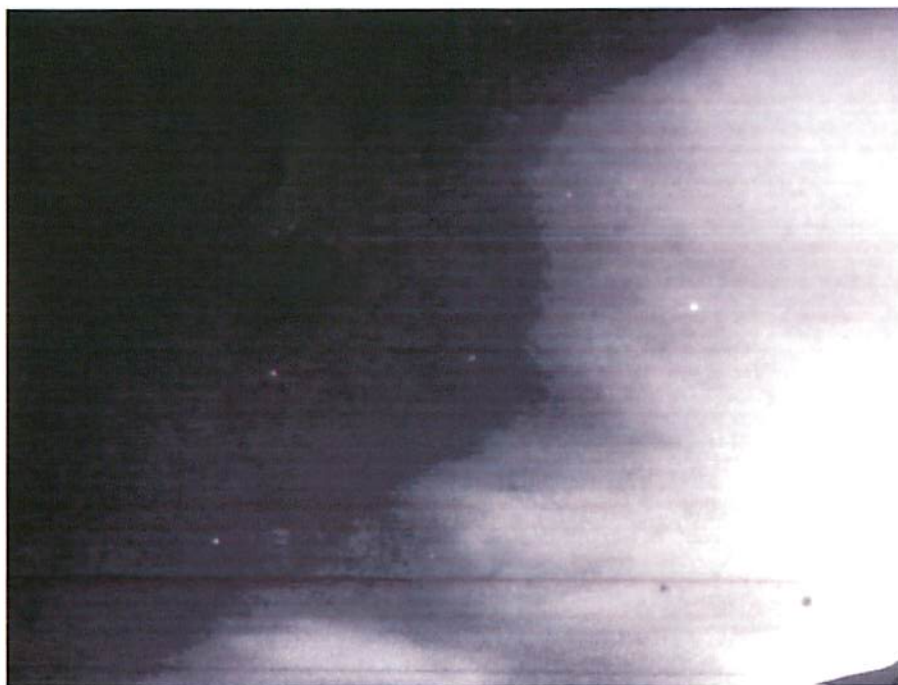
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# Image Comparison Bright Clouds Looking Towards Albuquerque (~ 40 Deg)



City Reflection off Clouds



ICCD Camera

City Reflection off Clouds + Sky Glow



SWIR Camera

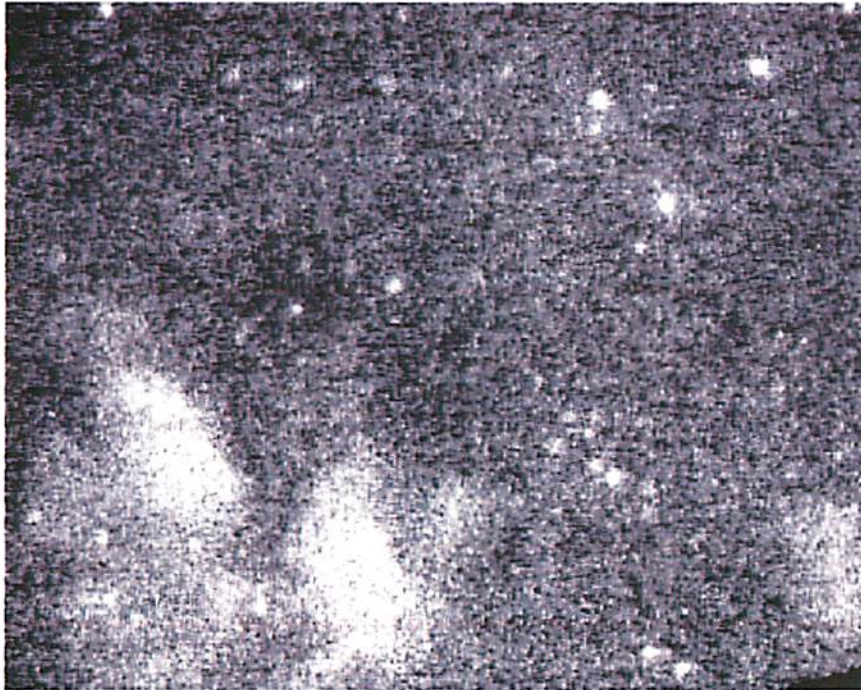
Sky Glow Irradiance  $\sim 2.1 \times 10^{-8} \text{ W/cm}^2$

Cloud Irradiance  $\sim 2.1 \times 10^{-8} \text{ W/cm}^2$

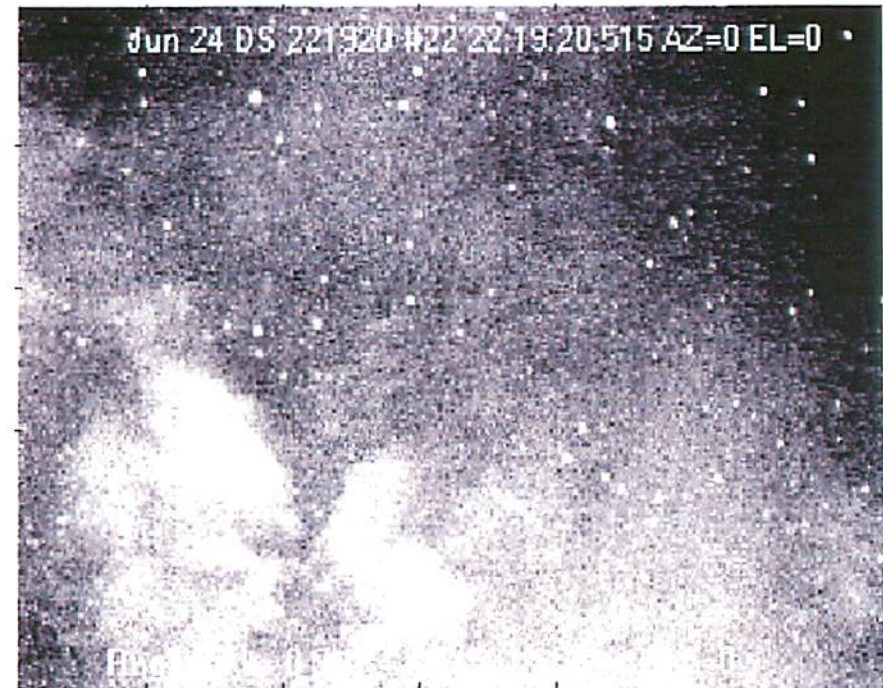


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# Image Comparison Near Zenith (~ 80 Deg)



ICCD Camera



SWIR Camera

Sky Glow Radiance  $\sim 4.2 \times 10^{-9} \text{ W/cm}^2$   
Cloud Radiance  $\sim 7.6 \times 10^{-9} \text{ W/cm}^2$



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## Image Comparison Near Zenith (~ 90 Deg)



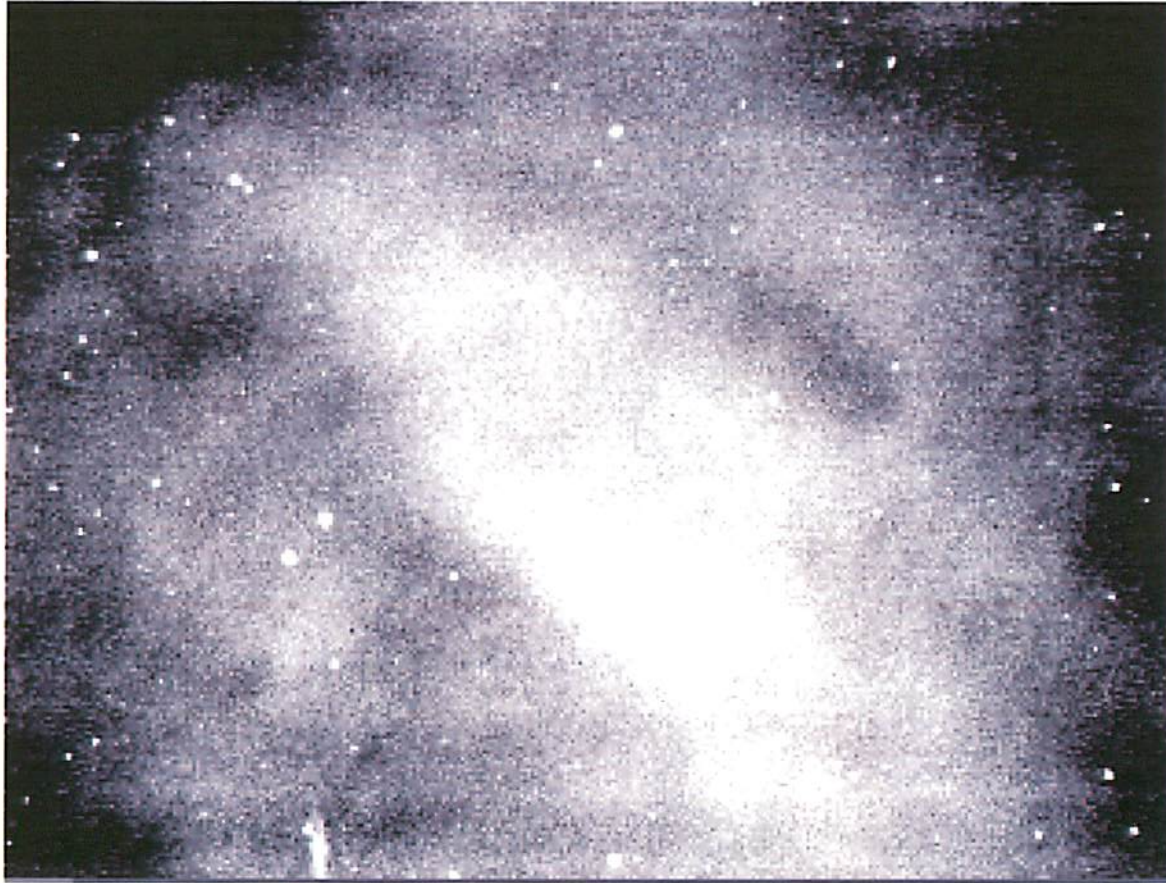
ICCD Camera



SWIR Camera

Sky Glow Radiance ~  $-3.0 \times 10^{-9} \text{ W/cm}^2$   
 $4.24 \times 10^{-9} \text{ W/cm}^2$

# Traveling Waves





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# Variation With Angle



**Zenith Angle**

**SWIR SKY Glow Radiance**

**20**

**$2.9 \times 10^{-8} \text{ W/cm}^2$**

**40**

**$2.1 \times 10^{-8} \text{ W/cm}^2$**

**80**

**$4.2 \times 10^{-9} \text{ W/cm}^2$**

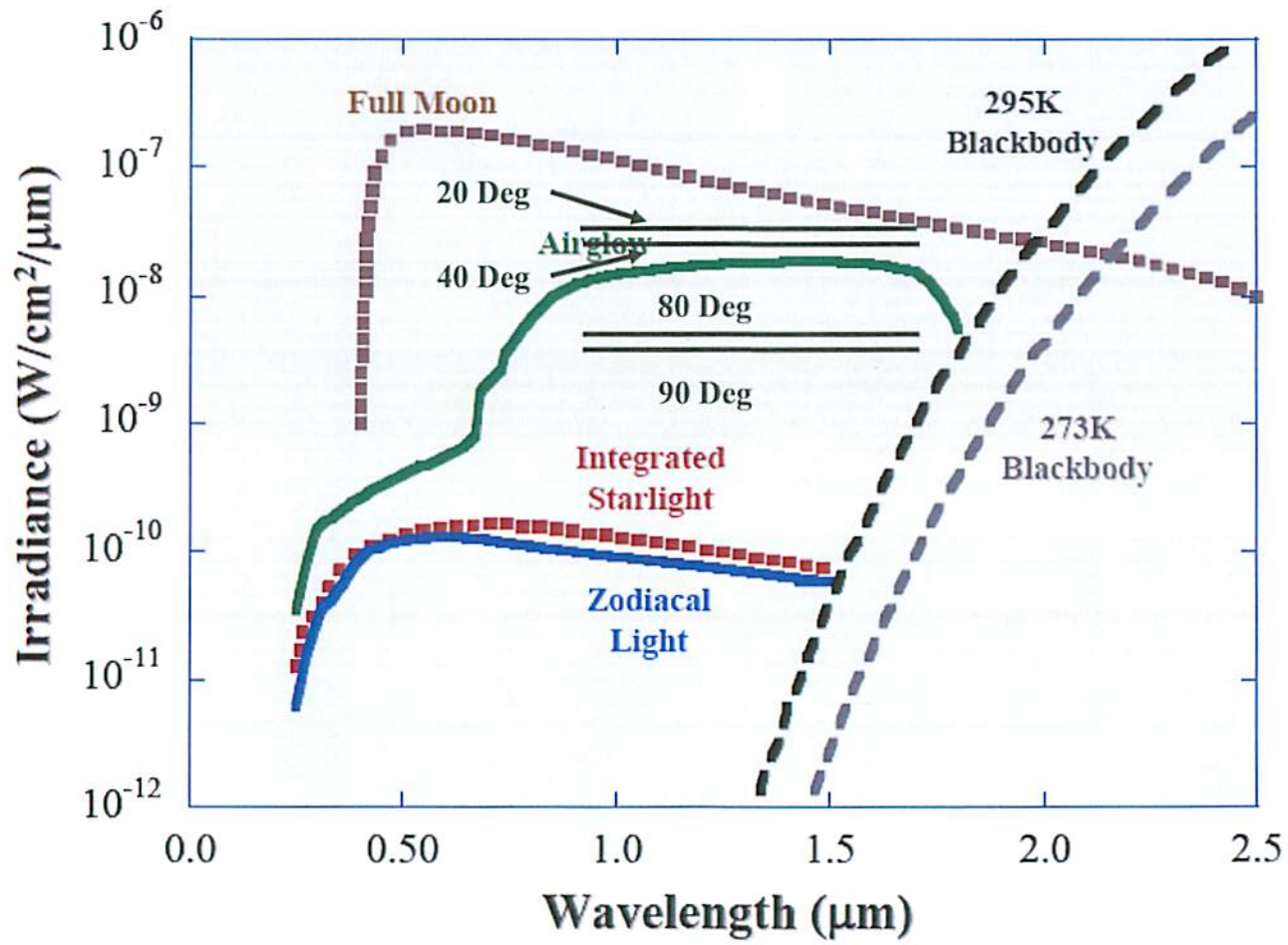
**90**

**$3.0 \times 10^{-9} \text{ W/cm}^2$**

**Integrated Measurement Over Sensor Bandwidth**

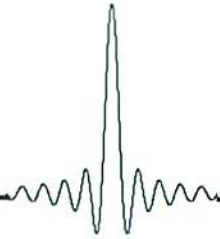
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# Measured Data Vs Models





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# Conclusions



- **SWIR Sky Glow**

- Chemical Luminescence
- Illumination for Passive Night Imaging
- Competes Favorably with Intensified Visible
- Measurements Compare Well to Published Models
- Order of Magnitude Variation with Zenith Angle

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